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STATE OF ALASKA

Walter J. Hickel, Governor

ANNUAL REPORT OF PROGRESS, 1966 - 1967

FEDERAL AID IN FISH RESTORATION PROJECT F-5-R-8

SPORT FISH INVESTIGATIONS OF ALASKA

ALASKA DEPARTMENT OF FISH AND GAME
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INTRODUCTION

This report of progress consists of findings and work accomplished under the State of Alaska Federal Aid In Fish Restoration Project F-5-R-8, "Sport Fish Investigations of Alaska."

The project during this report period is composed of 20 separate studies. Some are specific to certain areas, species or fisheries, while others deal with a common need for information. Each job has been developed to meet the needs of various aspects of the State's recreational fishery resource. Seven jobs are designed to pursue the cataloging and inventory of the numerous State waters. These are divided into logical utilization areas and are jobs of a continuing nature. It will be many years before an index of the potential recreational fishing waters is completed. Six jobs are directed toward specific sport fish studies. These include special efforts toward the anadromous Dolly Varden of Southeastern Alaska, silver salmon in Resurrection Bay, king salmon stocks on the lower Kenai Peninsula, king and other salmon stocks in Upper Cook Inlet, and Arctic grayling and sheefish in Interior Alaska. Special reports have been prepared on specific phases of the Dolly Varden life history and appear in the Department's special "Research Report" series.

The Statewide access evaluation remains one of the most important jobs conducted under this Federal Aid Program. It provides the Department with a tool to recommend withdrawal of suitable access sites on potential recreational fisheries throughout the State.

The remaining jobs include creel census efforts on specific fisheries in high use areas of the State, an egg-take program directed toward locating suitable indigenous stocks, perfecting advanced techniques in taking, handling and rearing species that are not normally associated with standard fish cultural practices, and continuation of the evaluation of the Fire Lake System.

The material contained in this report is often fragmentary in nature. The findings, evaluations and interpretations contained herein are subject to re-evaluation as the work progresses and additional data are collected.

Volume 8 Report No. 9-C-2

RESEARCH PROJECT SEGMENT

STATE: ALASKA Name: Sport Fish Investigations of Alaska.

Project No: F-5-R-8 Title: Evaluation of the Fire Lake Hatchery Water Supply.

Job No: 9-C-2

Period Covered: January 28, 1966 to January 19, 1967

ABSTRACT

Studies to evaluate the Fire Lake Hatchery water supply have been reported in Volumes 3, 4, 5, 6, and 7, Jobs 8-C-3 and 9-C-2, Dingell-Johnson Reports, State of Alaska, 1961-62; 1962-63; 1963-64; 1964-65; and 1965-66. This report is a continuation of the previous studies and will be the final report for this project.

The total streamflow of Fire Creek was estimated periodically during the period, and flows of 250 to 1,242 gpm were recorded. No estimates were made during the period of greatest streamflows in May. Estimates of the total quantity used in the hatchery varied from 95 to 258 gpm.

Periodic water samples from Upper Fire Lake were analyzed for dissolved oxygen, carbon dioxide, and pH. Dissolved oxygen levels ranged from 4.2 ppm on March 31 to 15.2 ppm on August 24, with both extremes occurring at the 20-foot depth. Carbon dioxide values of 1 to 12 ppm were recorded, and the pH of the lake waters ranged from 6.9 to 7.6. Temperatures in the lake ranged from a minimum of 32° F. to a maximum of 64° F. A maximum ice depth of 39 inches was recorded on March 15; the lake was ice free by early May. Ice reformed over the lake on October 25, and was approximately 16 inches thick at the end of the study period.

The hatchery water intake pipe was manipulated to provide the most satisfactory water temperatures possible. Hatchery water temperatures ranged from 36° F. to 57° F. Dissolved oxygen levels of water entering the hatchery varied from 4.5 ppm to 13.9 ppm.

Experiments to test the feasibility of recirculating water were conducted. Space heat in the hatchery building warmed the water a maximum of 12° F. Growth of fish in the recirculated water was greater and mortality lower than those in un-recirculated water. It was concluded that utilization of space heat is a feasible method of warming water for recirculation during the winter and spring.

Physical and chemical data from the water supply studies for all years were reviewed and evaluated, and provided a basis for preparing a preliminary manual for operating the hatchery's water supply facilities. This information will be incorporated into a more complete operation manual for the Fire Lake Hatchery at a later date.

RECOMMENDATIONS

It is recommended that this study be terminated. Periodic monitoring of some physical and chemical characteristics of the lake and hatchery water will be necessary in the future but will be a part of the hatchery routine.

It is recommended that compilation of streamflow data in Fire Creek be continued under, and as a part of, the Fire Lake Migration Study (Job 9-C-1).

OBJECTIVES

1. To determine the amount of water available for hatchery use and expansion of the rearing capacity.

2. To provide recommendations pertaining to the water supply for incorporation in an operating manual for the hatchery.

3. Investigate the feasibility of raising the operating water temperature during winter months.

TECHNIQUES USED

The quantity of water used in the hatchery was measured at irregular intervals during the year by recording the time required to fill containers of known volume, and converting to gallons per minute (gpm). Water flow in Fire Creek was determined by measuring the head behind the hatchery weir opening.

Water samples were collected from five depths near the intake tower in Upper Fire Lake and from several locations within the hatchery. Samples were analyzed for dissolved oxygen (DO) using a Hach direct reading colorimeter during part of the year, and using the Winkler method the remainder of the year; pH values were determined by use of a LaMotte color comparator; and carbon dioxide was determined by titration. Water temperatures of samples from the lake were taken with a pocket thermometer, and water temperatures in the hatchery were taken with a Taylor recording thermograph. Temperature and chemical data from previous years were compiled, reviewed, and evaluated.

Frequent difficulty was encountered during the year in obtaining consistent values of DO levels when using a Hach colorimeter. During May there was reason to question the accuracy of the technique when, in spite of apparent very low DO values, fish in one pond gave no indication of distress. Therefore, several series of comparisons were made between values obtained with the Hach colorimeter and those obtained by the Winkler method of titrating with solutions of sodium thiosulfate and/or Phenyl Arsene Oxide (PAO), a solution prepared by Hach Chemical Company, Ames, Iowa.

Initially, comparisons were made of values obtained by using dry crystal reagents and solutions, both prepared by Hach Chemical Company. Values were usually slightly higher when the dry reagents were used, but the differences did not appear significant. A single set of comparisons between values obtained by using sodium thiosulfate and PAO showed no significant differences.

It was assumed that values obtained by titration with either sodium thiosulfate or PAO were more accurate than those obtained with the Hach colorimeter. In Figure 1, the dissolved oxygen values determined with the Hach colorimeter are plotted in relation to values of identical samples obtained by titration. Values obtained with the Hach colorimeter were consistently much lower than those obtained by titration, and show a great deal more variability.

It is likely that some of the DO data compiled before changing to the titration technique would exhibit a similar relationship, but because of the observed variability, it is not feasible to attempt to apply a correction factor to the data. In this report, all DO values prior to June were obtained with the Hach colorimeter. The validity of the values shown during May are doubted, because it was at this time that we seriously questioned their accuracy. Beginning in June and continuing thereafter, all DO data were obtained by titration.

A diagram of the facility used to test the feasibility of recirculating water is presented in Figure 2. The principle involved in this system is that nitrogen-fixing bacteria break down metabolic wastes, especially ammonia and urea, into harmless nitrates. A relatively small quantity of fresh water is added continually to the system to remove some compounds and replace lost water.

A total of eight troughs was used in the system; four in the "A" series, and four in the "B" series. A total flow of 17 gpm was provided through the troughs, of which approximately 1.7 gpm was fresh water supplied directly from the hatchery water line. Heat was provided by space heat in the building. Filter and sump boxes were of plywood construction. The filter section was filled with approximately 1/2 cu. yd. of washed gravel and 50 pounds of oyster shell. The primary purpose of the filter material is to provide a surface for growth of the bacterial culture rather than serve as a debris filter. The oyster shell is used to maintain the pH of the recirculating water. The system was operated as follows:

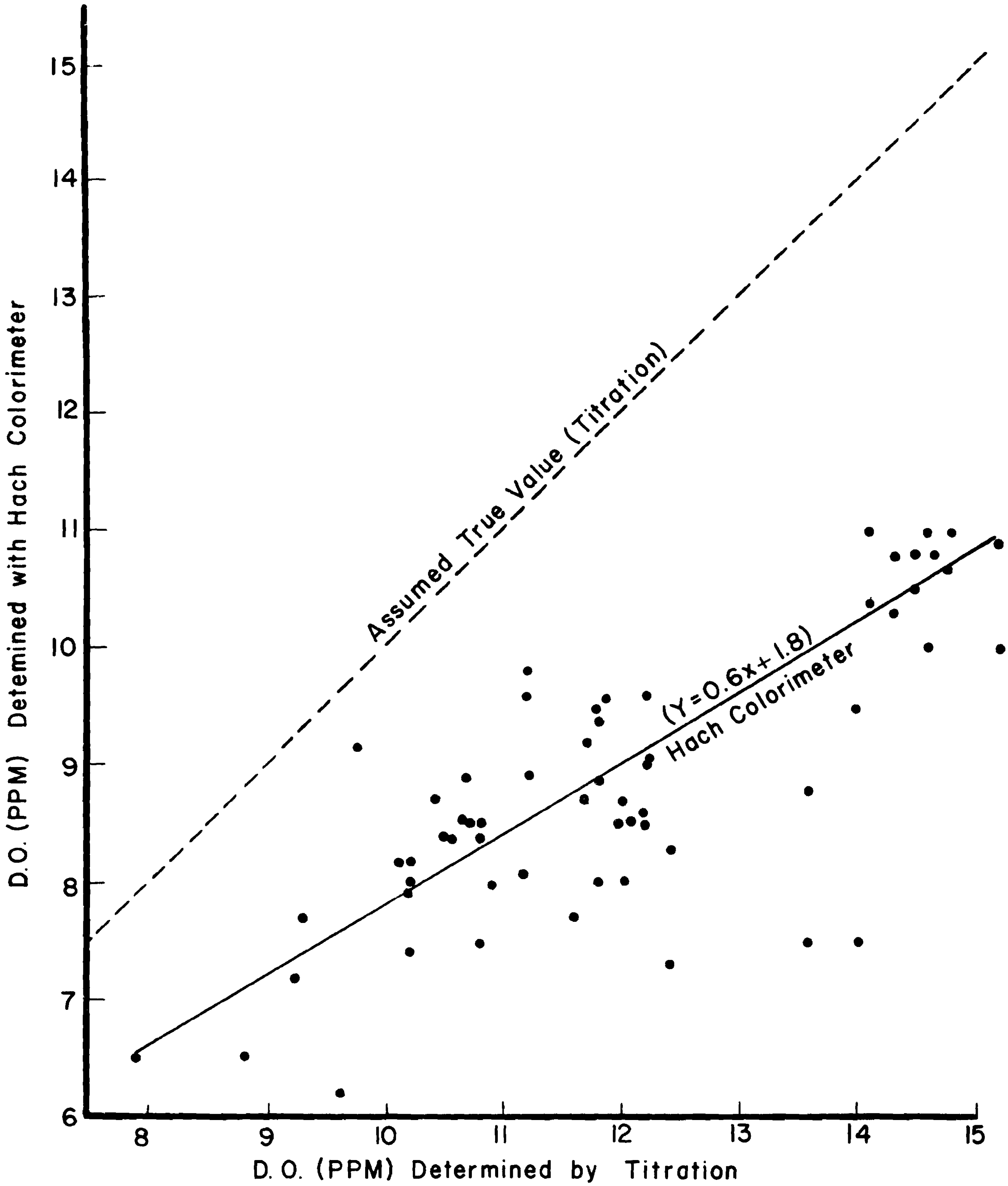

Figure 1. Scatter Diagram Showing Relationship Between Dissolved Oxygen Levels Determined by Titration with PAO and Sodium Thiosulfate and Determined with a Hach Direct Reading Colorimeter.

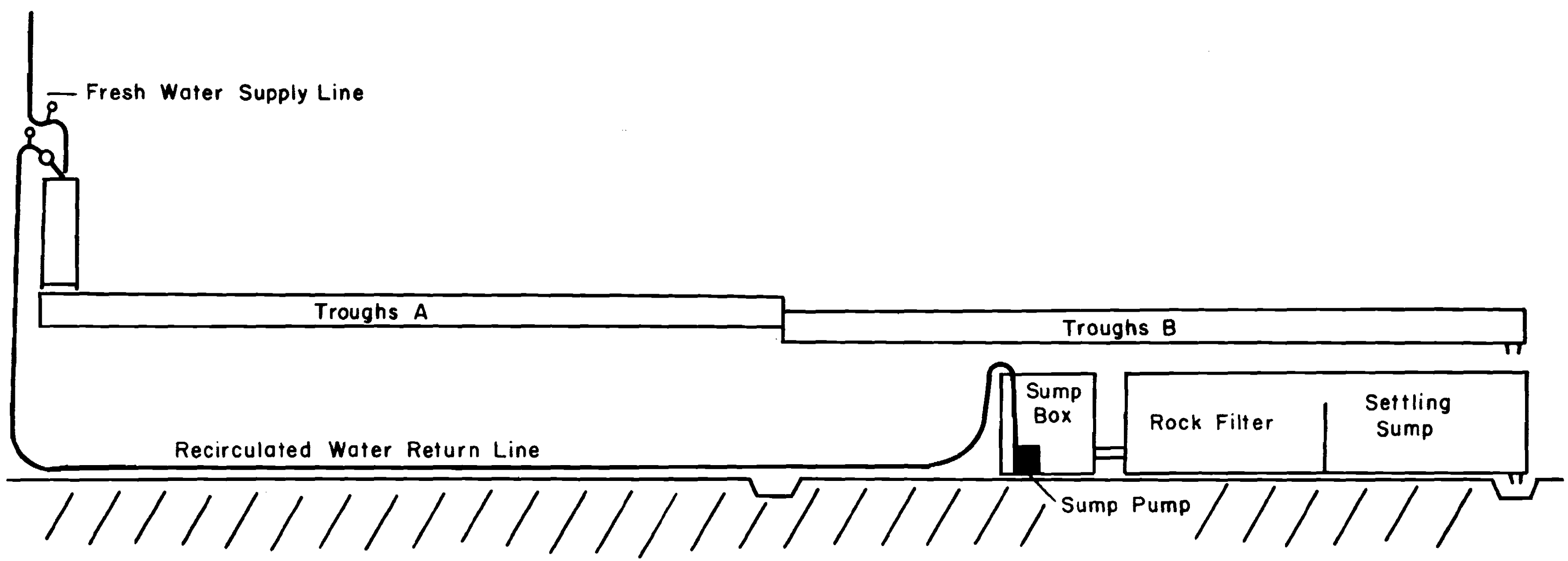

Figure 2. Schematic Diagram of Water Recirculation System Tested at Fire Lake Hatchery, 1966.

TABLE 1 - Water Flows in Fire Creek and Amount Used in the Hatchery, March 31, 1966 to January 12, 1967, in gpm.

	Hatchery Use				Fire Creek Flows			
Date	Troughs & Incubators	Ponds	By-Pass	Total	Above Hatchery	Over Weir	Est. Under Weir	Total Below Hatchery
3/31/66	75	150*	0	225	25	0	100	250
8/3/66	10	154	0	164	--	840	100	1,094
8/22/66	10	103	0	113	--	516	100	719
8/30/66	10	103	0	113	--	1,039	100	1,242
9/13/66	20	110	0	130	--	880	100	1,090
9/30/66	30	120	0	150	--	516	100	736
10/27/66	45	0	50	95	--	854	100	954
11/10/66	70	0	50	120	--	854	100	954
1/12/67	258	0	0	258	--	516	100	616

* Water used to melt ice in ponds.

TABLE 2 - Water Temperatures and Dissolved Oxygen Levels at Five Depths in Upper Fire Lake, January 28, 1966 to January 19, 1967.

	Depth in Feet									
	0'		5'		10'		15'		20'	
Date	Temp.	DO	Temp.	DO	Temp.	DO	Temp.	DO	Temp.	DO
1/28/66	33	9.9	34	9.3	36	8.8	37	8.5	37	8.0
2/11/66	33	8.3	34	8.2	37	8.2	37	8.1	38	7.7
2/15/66	32	8.7	34	8.4	37	8.2	38	8.1	38	8.0
2/28/66	32	8.0	33	7.5	34	7.7	38	7.2	38	6.5
3/15/66	33	7.9	34	7.1	36	6.5	37	6.3	39	6.4
3/31/66	33	6.0	34	5.5	37	5.2	38	4.8	38	4.2
4/29/66	38	7.2	42	7.0	41	6.5	40	5.7	40	6.7
5/19/66*	42	6.2	43	6.5	42	6.5	42	6.6	42	6.7
6/21/66	58	11.2	58	11.6	51	10.6	50	12.0	48	11.6
7/30/66	64	10.2	63	10.8	58	10.4	54	14.6	50	11.6
8/1/66	64	10.1	63	10.2	58	13.4	56	14.2	51	14.0
8/12/66	60	10.7	60	10.6	58	11.4	53	14.4	49	14.1
8/24/66	56	11.8	55	11.2	55	11.2	53	12.2	50	15.2
8/31/66	55	11.0	54	10.4	54	12.4	52	11.0	50	14.2
9/21/66	50	12.0	50	12.2	50	12.2	50	12.1	49	10.9
10/18/66	40	10.0	41	10.0	41	9.8	41	9.8	40	9.8
11/29/66	33	--	35	10.2	36	10.0	36	10.0	38	9.4
12/21/66	--	--	34	10.0	36	9.6	36	9.8	36	9.2
1/19/67	32	10.2	34	9.6	36	9.2	37	8.8	37	7.4

* Questionable validity.

Water was introduced at the head of troughs "A" through baffle aerators, then flowed through both sets of troughs "A" and "B", and was discharged into the settling sump. From the settling sump the water flowed over a baffle divider into the top of the gravel filter compartment, then downward through the gravel, and was picked up by a series of perforated drain pipes in the bottom and delivered into the sump box through a pipe. A sump pump then pumped the water back to the aerators at the head of troughs "A". During operation of the recirculation system, water temperatures were recorded with a Taylor recording thermograph.

FINDINGS

Flow Data

The estimated hatchery use of water from Upper Fire Lake and streamflow data in Fire Creek are listed in Table 1.

Maximum water use inside the hatchery ranged from a minimum of about 10 gpm during August, when only two stacks of incubators were in operation, to a maximum of 258 gpm in January, 1967, when all troughs and all incubators contained eggs and fry. Maximum use in the outdoor ponds occurred in August when three ponds were in use simultaneously. The bypass valve immediately above the hatchery, used for greater flows through the pipeline to prevent freezing, was in use until the outside ponds were put into operation on March 28, and again during October and November when the flow through the hatchery was small. The bypass valve was shut off in December when the hatchery water demand increased.

The maximum flow in Fire Creek occurred during March and April. Total flows in Fire Creek, from data obtained during 1966-67 and reported for 1962-63 (Stefanich, 1963), are illustrated graphically in Figure 3. It is apparent that the streamflow data are limited.

Water Quality

Water temperatures recorded in Upper Fire Lake (Table 2) ranged from 32° F. to 64° F. The temperature regime was very similar to that observed in previous years. The maximum ice depth on the lake was 39 inches, recorded on March 15, 1966 (Table 3), and the maximum snow cover was 15 inches, recorded on January 19, 1967. The ice cover on the lake melted in early May and re-formed on October 25.

TABLE 3 - Ice and Snow Cover on Upper Fire Lake, January 28, 1966 to January 19, 1967.

Date	Ice Depth (Inches)	Snow Depth (Inches)
1/28/66	29	8
2/11/66	31	11
2/15/66	31	8
2/28/66	36	12
3/15/66	39	12
3/31/66	37	4
4/29/66	25-1/2	0
	Ice out approximately 5/10	
	Ice formed 10/25	
11/29/66	10	8-1/2
12/21/66	15	7
1/19/66	16	15

Dissolved oxygen levels varied from a low of 4.2 ppm on March 31, to a high of 15.2 ppm on August 24, with both extremes occurring at the 20-foot depth (Table 2). During the period 1962 to date, DO values have ranged from a minimum of 1.8 ppm (4/11/63) to a maximum of 15.2 ppm (8/24/66), with both extremes occurring at the 20-foot depth.

Mean monthly DO levels are shown graphically in Figure 4 to illustrate the annual changes that occur in the lake. The data used for illustration are those obtained during 1966, and while there are some differences in values from previous years, the pattern is

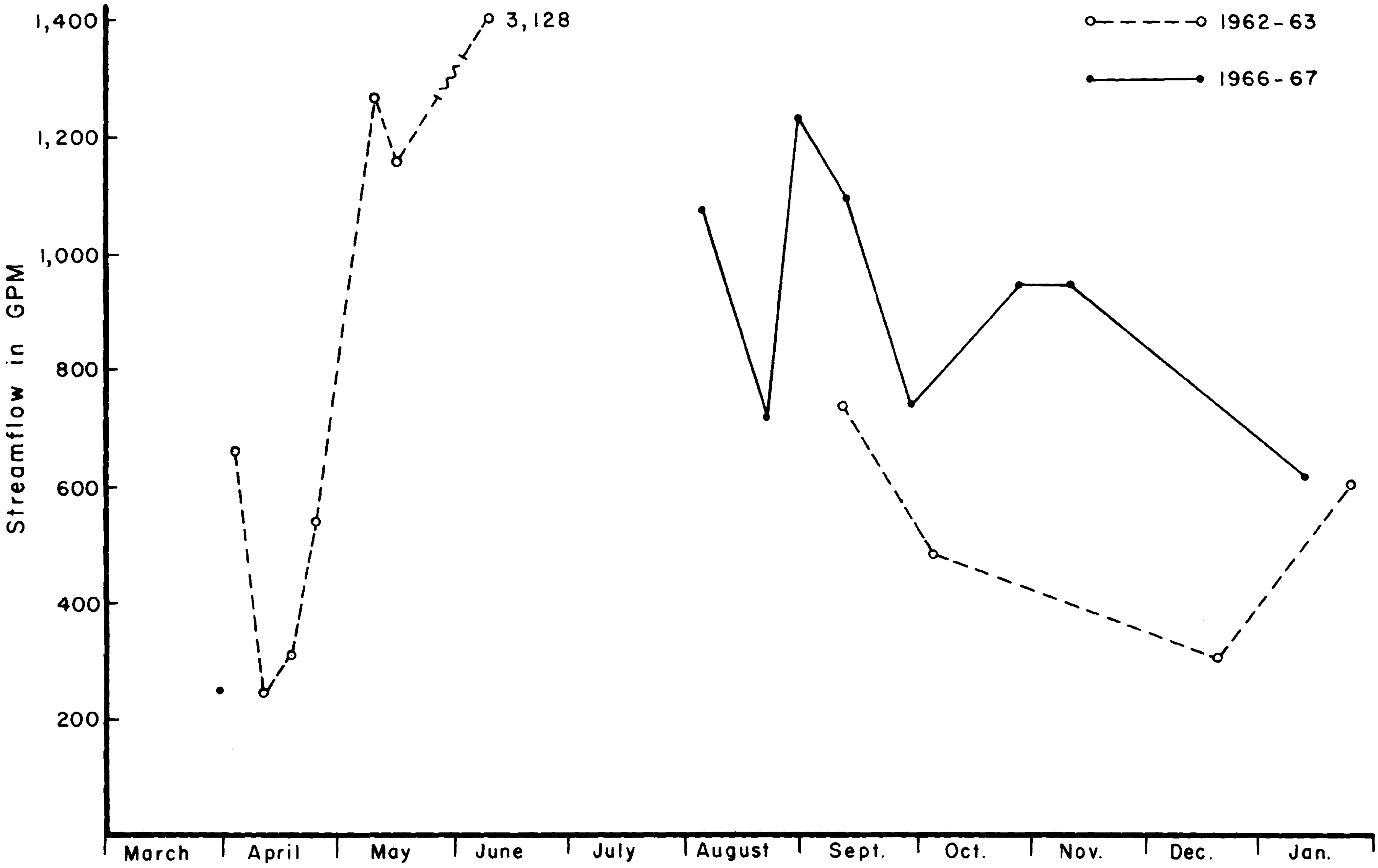

Figure 3. Estimated Total Streamflow in Fire Creek, 1962-63 and 1966-67.

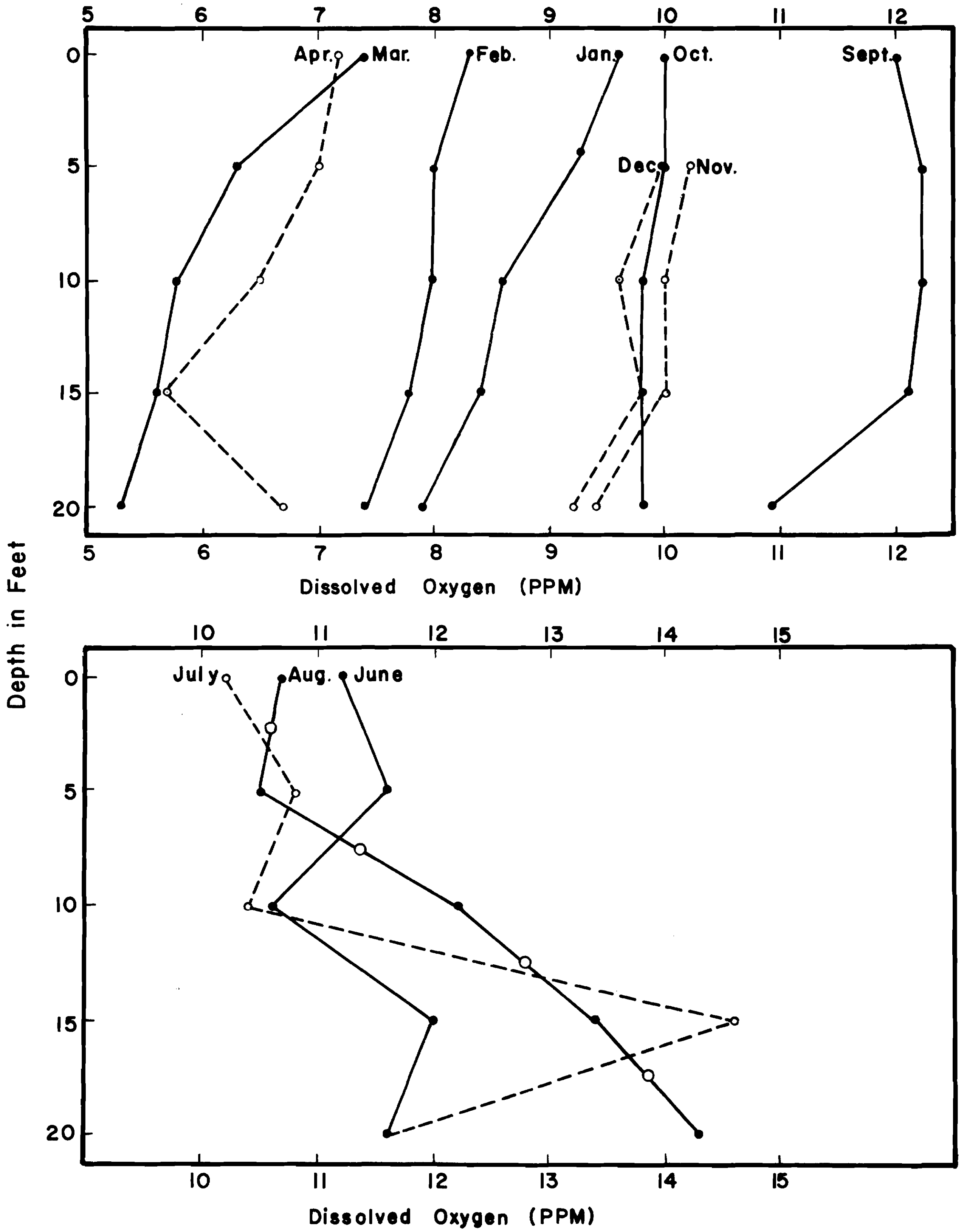

Figure 4. Profile of Mean Monthly Dissolved Oxygen Levels in Upper Fire Lake During 1966.

TABLE 4 - Dissolved Oxygen Levels (ppm) at Several Locations in the Fire Lake Hatchery, January 15, 1966 to January 19, 1967.

Date	Head of Trough		Foot of Trough	Heath Incubators		Hatching Boxes	
	W/O Aeration	W/Baffle Aerators		Top Tray	Bottom Tray	Headbox	Box Outlet
1/15/66	---	---	---	---	8.6 - 9.0	---	---
1/25/66	7.6	---	---	---	8.0 - 8.3	---	---
1/28/66	7.5	---	7.8	---	7.9	---	---
2/9/66	6.5	8.1	7.5	7.0	7.2	---	---
2/11/66	6.2	7.2	7.0	6.5	7.0	---	---
2/15/66	8.0	9.0	---	---	---	---	---
2/17/66	7.0	9.0	---	7.0	7.7	---	---
2/23/66	7.0	9.5	---	7.0	7.5 - 8.0	---	---
2/28/66	6.5	8.2	---	7.0	7.5 - 8.4	---	---
3/7/66	5.7	---	---	6.0 - 6.5	5.6 - 5.8	---	---
3/14/66	5.8	---	---	8.2 - 8.4 *	6.8 - 8.0	---	---
3/15/66	---	---	---	7.8	7.2	---	---
3/30/66	5.0	5.5	5.5	6.8	6.0	---	---
4/1/66	4.5	5.5	4.5 - 5.0	---	---	---	---
4/9/66	4.5	6.2	6.0 - 6.2	---	---	---	---
4/16/66	4.5	6.0	5.6 - 6.7	7.7	5.5	---	---
4/29/66	5.4	6.5	5.8 - 6.5	7.2	6.8	---	---
5/19/66 **	---	7.2	6.6 - 6.7	7.0	5.5	---	---
6/21/66	---	12.0	6.8 - 9.4	---	---	---	---
7/31/66	13.9	---	---	---	---	---	---
8/12/66	---	11.8	10.2	---	---	---	---
9/21/66	11.2	---	---	---	---	---	---
11/29/66	---	9.4	9.4	10.4	11.0	---	---
1/19/67	7.6	---	8.0	8.4	9.6	7.2	7.0

* Headbox with spray inlet pipe installed.
** Questionable validity.

similar. During the fall overturn oxygen is well mixed throughout the lake. Through November and December there is little change in DO levels except for a slight reduction at the 20-foot depth. By January there are reduced DO levels at all depths, becoming more pronounced with increasing depth. The reduction continues through February, March, and early April when minimum DO values are recorded. The spring overturn begins in April and results in equalization of DO levels at all depths in April or May. As soon as the snow and ice cover are removed and wind action and photosynthesis begins, there is an increase in DO throughout the lake. During July and August there is a pronounced increase in DO at increased depths. When the fall overturn begins in September, DO levels at all depths are high due to mixing of oxygen-rich water from the deeper areas.

The high DO levels at the 15- and 20-foot depths were first encountered on July 30. Repeated testing, varying and checking techniques, and testing by the USGS laboratory in Anchorage confirmed the validity of the first results. The levels encountered would be supersaturated at the temperatures near the surface and if under only atmospheric pressure, but at the temperatures near the bottom and under pressure (6.7 and 9.0 psi at 15- and 20-foot depths, respectively), they are not supersaturated. The most plausible explanation for the increase in oxygen is that it is produced by photosynthetic action during long periods of daylight, and wind action is not great enough to mix the waters in the lake and expose the deeper waters to atmospheric pressures.

Dissolved oxygen levels were monitored at several locations within the hatchery throughout the year (Table 4). The lowest DO recorded was 4.5 ppm in water taken directly from the head pipe and was recorded on three occasions during April. The highest DO was 13.9 ppm recorded on July 31.

In early February, DO levels in water entering the hatchery dropped below 7 ppm, the minimum desired level. The aluminum baffle aerators were installed at the inlet of each trough in which there were eggs or fry, increasing the DO to the troughs from a low of 0.5 to 2.5 ppm.

It was found that DO increased between the top and bottom trays of the Heath incubators. However, as fry development progressed, creating an increased demand for oxygen, the amount of oxygen in the bottom incubator trays decreased during early March. A wooden headbox was installed over the incubators, and the supply line to the headbox was perforated to spray into the box and aerate the water. This increased DO levels in the incubators and maintained them at a satisfactory level during most of the incubation period.

Carbon dioxide levels in samples tested from Upper Fire Lake ranged from 1 ppm to 2 ppm (Table 5). Higher levels were recorded during the winter and spring, but no consistent relationship with depth or DO was observed. The range in CO_2 values is comparable to those recorded in previous years. Overall, the CO_2 concentrations are at a level that should present no problems in operations.

TABLE 5 - Carbon Dioxide and pH Levels from Five Depths in Upper Fire Lake, January 28, 1966 to January 19, 1967.

	CO_2 (ppm) Depth (feet)					pH Depth (feet)				
Date	0	5	10	15	20	0	5	10	15	20
1/28/66	9	9	7	7	9	7.1	7.1	7.1	7.1	7.1
2/15/66	5	8	7	7	6	7.2	7.1	7.1	7.1	7.1
2/28/66	8	7	6	7	8	7.1	7.1	7.0	7.1	7.1
3/15/66	12	10	10	11	9	6.9	7.0	7.1	7.1	7.1
3/30/66	5	6	7	9	10	7.1	7.1	7.1	7.1	7.1
5/19/66	9	9	9	9	9	7.2	7.2	7.2	7.2	7.2
7/30/66	2	2	2	2	4	---	---	---	---	---
8/24/66	5	3	3	3	1	---	---	---	---	---
11/29/66	-	4	4	6	10	---	---	---	---	---
12/21/66	-	5	5	5	9	---	---	---	---	---
1/19/67	7	7	8	8	11	7.6	7.4	7.4	7.4	7.4

During the period, pH values of the samples tested ranged from 6.9 to 7.6. In compiling pH data from previous years, it was obvious there was a great deal of erratic variation, especially between adjacent sampling dates. During years when this variation was the greatest, the Hach colorimeter was used for pH determinations. Preliminary tests with this colorimeter in 1966 demonstrated that it could not be relied upon, therefore was not used. It is likely that differences in techniques used were responsible for some of the past variation.

No tests for alkalinity were made during this period. Data from previous years shows that the total alkalinity ($CaCo_3$) has been in the range of about 70 to 85 ppm, although a minimum of 36 ppm and a maximum of 111 ppm were recorded.

Collection of gas in the pipeline was a persistent problem throughout the summer, and it was released from the line when the pressure on the supply line in the hatchery got as low as approximately 10 psi. The frequency of releasing the gas varied from once a week to once every other day, and, in general, was related to the quantity of water being used.

Large quantities of vegetation (dying aquatic plants) and stickleback get into the pipeline and create a serious problem in maintaining water to the troughs and incubators. Valves and small aperatures in pipes became plugged, making it necessary to install screen boxes over the headbox supply lines to prevent lines to individual incubators and hatching boxes from plugging. At present it is not possible to screen inlet pipes to individual troughs. Constant surveillance is necessary. The problem was most serious during March and April and again during December and January, the periods of maximum demand for water inside the hatchery.

Water Recirculation

The water recirculation system was operated intermittently from March 25 to May 4. Incoming water temperatures and the maximum temperatures achieved in the system are shown in Figure 5. Minimum water temperatures in the system for most days were about the same as the incoming temperatures due to replacing water in the system during trough cleaning and filter back-flushing, and are not shown. The maximum warm-up was 12° F. above the temperature of incoming water but the usual increase was 6° F. to 8° F. It was possible to control the temperature between the maximum warm-up and incoming water temperature by adjusting the quantity of new water added.

Two experiments were conducted to determine the feasibility of rearing fish in the system and to determine the effect of warmer water on growth and mortality. In both experiments unfed silver salmon fry of Swanson River origin were the test animals. Each trough was stocked with 17,500 fry at the start of the experiment (Table 6). In the first test, four troughs of fish were used in the recirculating system and four troughs with water directly from the supply line were used as controls. In the second experiment, only two troughs in the recirculating system were used and two adjacent troughs served as controls.

In both experiments growth was greater and mortality lower in the lots in the recirculated water than those in fresh water. However, the differences in mortality were not significant in either experiment, and the increased growth in only the second experiment was significant. In spite of increased growth of fish in warmer water in the second experiment, growth was poor in all lots in both experiments; this is believed to have been due to an inadequate diet.

Problems in maintaining water temperatures were encountered when cleaning troughs and back-flushing filters. Due to the small size of the total system, a large portion of water in the system was discharged during trough cleaning and had to be replaced with fresh water. This reduced the temperature to near that of the incoming water. Excrement and uneaten food promoted a luxurious fungus growth that would plug the filter in two or three days, and it was necessary to back-flush the filter frequently. While back-flushing, fresh water was used in the troughs. Then the system had to be refilled, also reducing temperatures.

From these experiments, as well as results of work conducted at the U.S.F.W.S. Salmon Cultural Laboratory, Longview, Washington, where the technique was developed, it was concluded that it would be feasible to use this type of recirculation system to permit warming of the rearing water during the winter and spring. A production system must be designed so that routine cleaning and back-flushing operations do not disrupt operation of the system. It would also be necessary to incorporate a method of direct heating of water in a production installation.

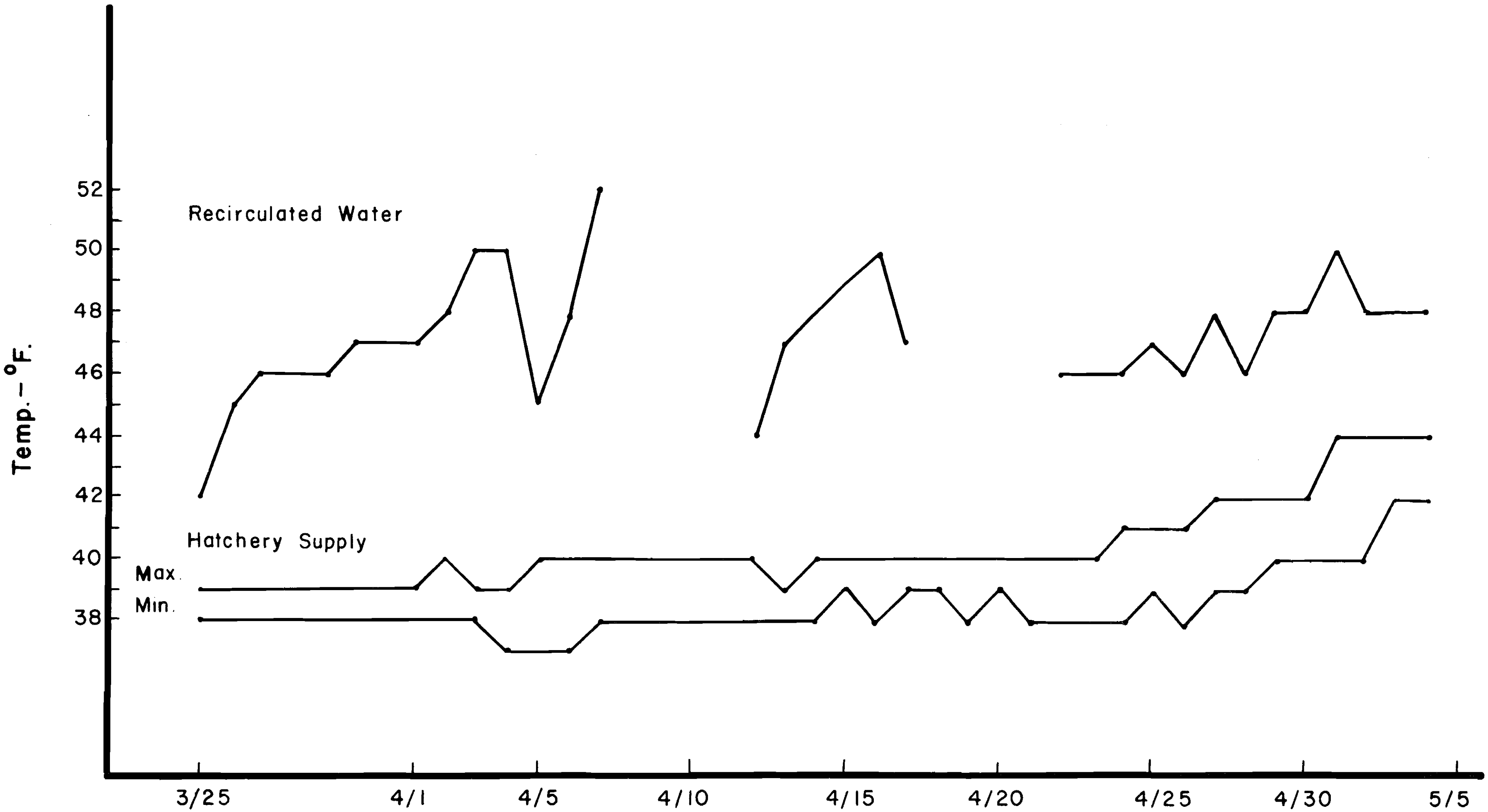

Figure 5. Water Temperatures of Fire Lake Hatchery Water Supply and Recirculated Water, March 25 to May 4, 1966.

TABLE 6 - Data from Two Experiments in Rearing Silver Salmon in Recirculated Water System at Fire Lake Hatchery, 1966.

Trough No.	Start of Experiment: Date	Number Fish	Total Weight (Gms.)	Average Weight: Gms.	Average Weight: Fish/lb.	End of Experiment: Date	Number Fish	Total Weight (Gms.)	Average Weight: Gms.	Average Weight: Fish/lb.	Average Weight Gain %	Mortality: No.	Mortality: %
Experimental													
3	3/25	17,500	3,742	0.214	2,121	4/16	17,343	4,345	0.251			157	
4	3/25	17,500	3,742	0.214	2,121	4/16	17,327	4,440	0.256			173	
5	3/25	17,500	3,742	0.214	2,121	4/16	17,214	4,465	0.259			286	
6	3/25	17,500	3,742	0.214	2,121	4/16	17,334	4,425	0.255			166	
TOTAL		70,000	14,968	0.214	2,121		69,218	17,675	0.255	1,778	19	782	1.1
Control													
7	3/25	17,500	3,742	0.214	2,121	4/16	17,298	4,190	0.242			202	
8	3/25	17,500	3,742	0.214	2,121	4/16	17,145	4,240	0.247			355	
9	3/25	17,500	3,742	0.214	2,121	4/16	17,215	4,290	0.249			285	
10	3/25	17,500	3,742	0.214	2,121	4/16	17,246	4,180	0.242			254	
TOTAL		70,000	14,968	0.214	2,121		68,904	16,900	0.245	1,851	14	1,096	1.6
Experimental													
3	4/20	17,500	3,814	0.218	2,083	4/16	16,710	4,745	0.284			790	
4	4/20	17,500	3,814	0.218	2,083	4/16	16,931	4,775	0.282			569	
TOTAL		35,000	7,628	0.218	2,083		33,641	9,520	0.283	1,603	30	1,359	3.9
Control													
5	4/20	17,500	3,814	0.218	2,083	4/16	16,672	3,770	0.226			828	
6	4/20	17,500	3,814	0.218	2,083	4/16	16,665	3,800	0.228			835	
TOTAL		35,000	7,628	0.218	2,083		33,337	7,570	0.227	1,998	4	1,663	4.8

LITERATURE CITED

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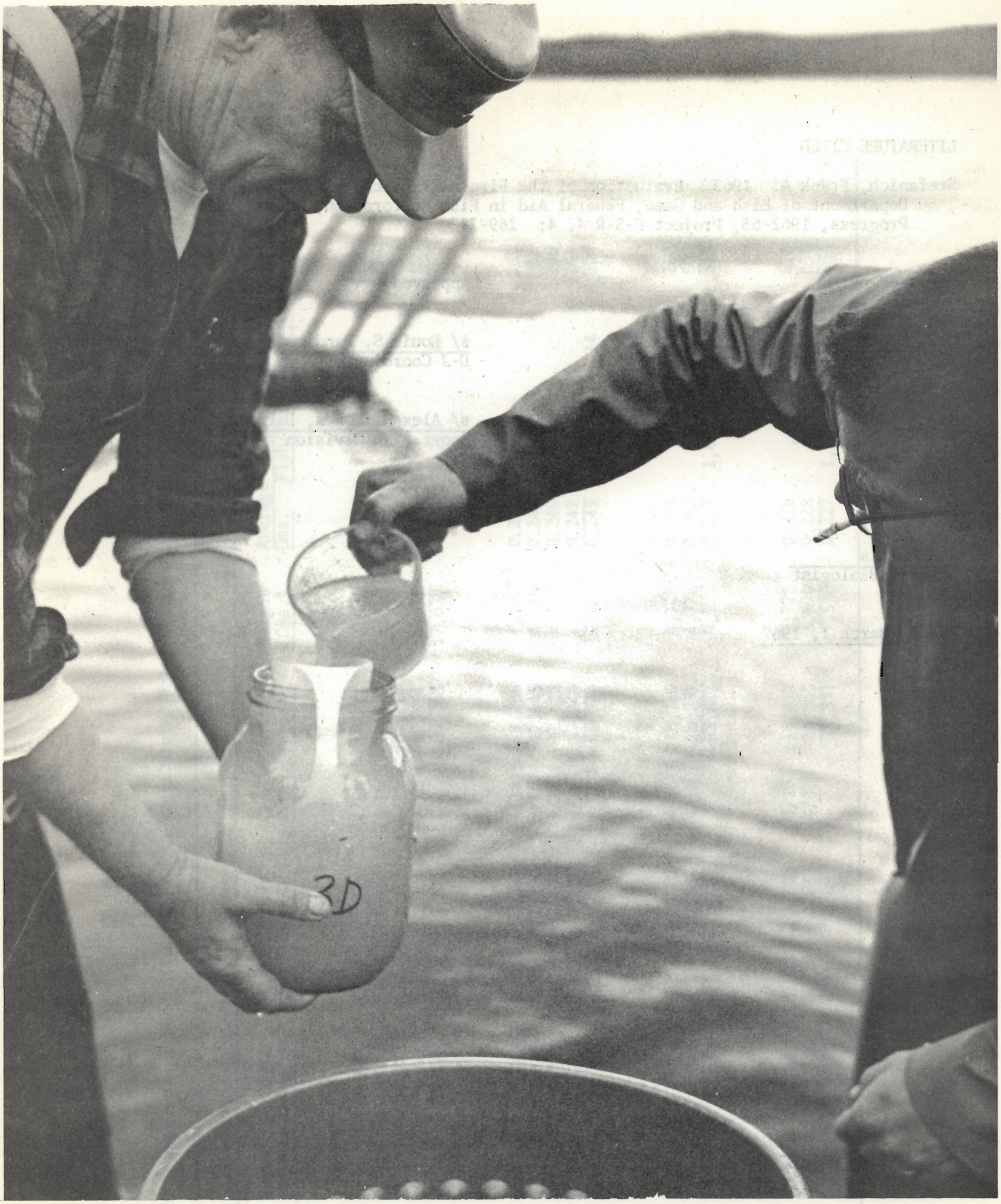

Fertilized Arctic Grayling Eggs are Measured Volumetrically Prior to Shipment to the Hatchery.